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MECHANICAL ENGINEERING SECTION

F A X T R A N S M I T T A L

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MESSAGE: Per your request, attached
is the data on 800H material.
RK

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INCOLOY alloy 800H is a version of INCOLOY alloy 800 having significantly higher creep and rupture strength. The two alloys have the same chemical composition with the exception that the carbon content of INCOLOY alloy 800H is restricted to the upper portion of the standard range for alloy 800. The limiting chemical composition of alloy 800H is shown in Table 19.

In addition to a controlled carbon content, INCOLOY alloy 800H receives an annealing treatment that produces a coarse grain size—an ASTM number¹³ of 5 or coarser. The annealing treatment and carbon content are responsible for the alloy's greater creep and rupture strength.

The mechanical properties of INCOLOY alloy 800H, combined with its resistance to high-temperature corrosion, make the alloy exceptionally useful for many applications involving long-term exposure to elevated temperatures or corrosive atmospheres. In chemical and petrochemical processing the alloy is used in steam/hydrocarbon reforming for catalyst tubing, convection tubing, pigtails, outlet manifolds, quenching-system piping, and transfer piping; in ethylene production for both convection and cracking tubes; in oxo-alcohol

production for tubing in hydrogenation heaters; in hydrodealkylation units for heater tubing; and in production of vinyl chloride monomer for cracking tubes, return bends, and inlet and outlet flanges.

Industrial heating is another area of wide usage for INCOLOY alloy 800H. In various types of heat-treating furnaces, the alloy is used for radiant tubes, muffles, retorts, and assorted furnace fixtures.

Alloy 800H is also used in power generation for steam superheater tubing and high-temperature heat exchangers in gas-cooled nuclear reactors.

Table 19—Limiting Chemical Composition, %, of INCOLOY alloy 800H

Nickel.....	30.0-35.0
Chromium.....	19.0-23.0
Iron.....	39.5 min
Carbon.....	0.05-0.10
Manganese.....	1.50 max
Sulfur.....	0.015 max
Silicon.....	1.0 max
Copper.....	0.75 max
Aluminum.....	0.15-0.60
Titanium.....	0.15-0.60

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Physical constants and thermal properties

Since the compositional range for INCOLOY alloy 800H falls within that for INCOLOY alloy 800, the two alloys show no significant differences in physical and thermal properties. Values for various properties are given in Tables 2, 3, and 4 and Figure 1.

Mechanical properties

The major differences between alloys 800 and 800H are in mechanical properties. The differences stem from the controlled carbon content of alloy 800H and the high-temperature anneal used for the alloy. In general, alloy 800 has higher mechanical properties at room temperature and during short-time exposure to elevated temperatures, whereas alloy 800H has superior creep and rupture strength during extended high-temperature exposure.

Tensile properties

Typical tensile properties of INCOLOY alloy 800H at temperatures to 2000°F (1095°C) are shown in Figure 15. The data are for annealed extruded tubing of 5-in. (127-mm) outside diameter and 0.5-in. (12.7-mm) wall.

Tensile properties and hardness of alloy 800H at room and elevated temperatures are shown in Table 20. The tests were performed on annealed plate, 0.813 in. (20.7 mm) thick.

Impact strength

INCOLOY alloy 800H exhibits high impact strength and retains substantial toughness after long-time exposure to elevated temperatures. Charpy V-notch tests on three different lots of annealed material gave an average room-temperature impact strength of >239 ft-lb (324 J). Table 21 shows impact strength of cold-rolled (20%) material after extended expo-

sure to high-temperatures. The cold-rolled condition was used to accelerate any precipitation reactions during exposure.

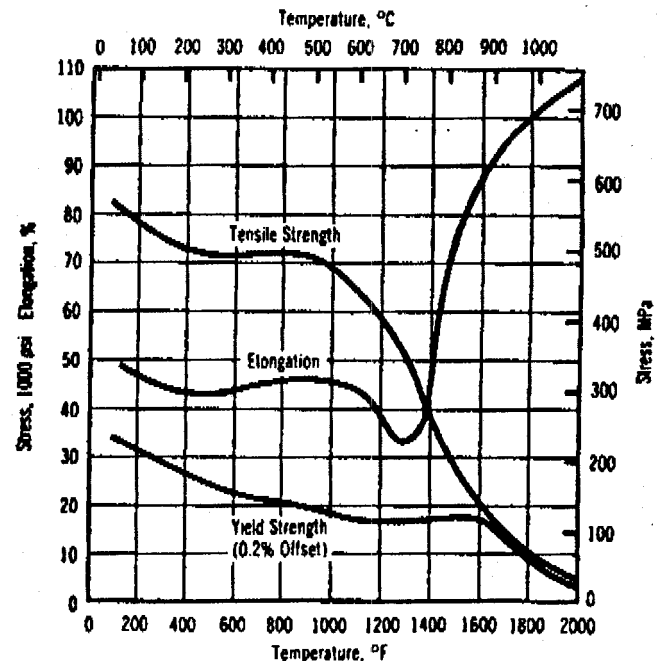


Figure 15. High-temperature tensile properties of INCOLOY alloy 800H.

Table 20—Tensile Properties and Hardness of INCOLOY Alloy 800H at High Temperatures

Temperature		Hardness, BHN	Tensile Strength		Yield Strength (0.2% Offset)	
°F	°C		psi	MPa	psi	MPa
80	27	126	77,800	536	21,700	150
800	425	—	67,500	465	18,800	130
1000	540	90	62,700	432	13,000	90
1200	650	84	54,800	378	13,500	93
1300	705	82	47,700	329	15,800	109
1400	760	74	34,200	236	13,100	90

Table 21—Room-Temperature Properties of Cold-Rolled (20%) INCOLOY alloy 800H After High-Temperature Exposure

Exposure Temperature		Exposure Time, h	Impact Strength*		Yield Strength (0.2% Offset)		Tensile Strength		Elongation, %	Reduction of Area, %
°F	°C		ft-lb	J	1000 psi	MPa	1000 psi	MPa		
No Exposure		—	112	152	113.0	779	114.0	786	15.5	58.0
1000	540	1,000	63	85	114.5	789	127.5	879	18.5	50.5
		4,000	78	106	112.5	776	125.5	865	20.0	52.5
		8,000	61	83	113.5	783	128.5	886	20.0	47.0
		12,000	61	83	113.5	783	128.5	886	20.0	52.0
1200	650	1,000	87	118	90.5	624	109.0	752	23.0	46.5
		4,000	65	88	79.4	547	107.0	738	21.5	43.0
		8,000	62	84	81.4	561	106.5	734	25.5	52.5
		12,000	63	85	78.9	544	105.0	724	24.0	50.0

* Charpy V-notch tests.

Fatigue strength

Low-cycle fatigue strength of alloy 800H at room temperature and 1400°F (760°C) is shown in Figure 16.¹⁴ Low-cycle fatigue data for alloys 800 and 800H are compared at 1000°F (538°C) and 1200°F (649°C) in Figures 17 and 18.

Creep and rupture properties

The outstanding characteristic of INCOLOY alloy 800H is its high creep and rupture strength. The alloy's carbon content and annealing treatment are designed to produce optimum creep-rupture properties in material having the standard INCOLOY alloy 800 composition. Figure 19 shows creep strength of alloy 800H at various temperatures.

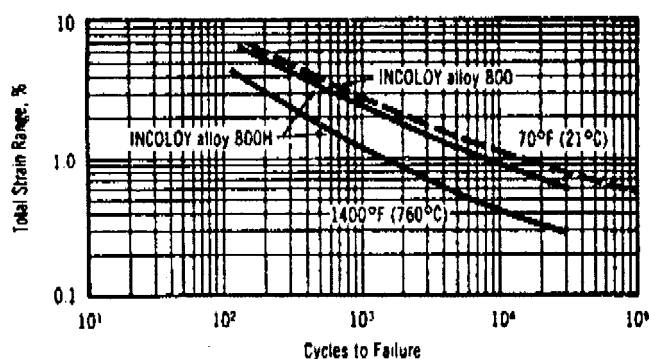


Figure 16. Low-cycle fatigue strength of INCOLOY alloy 800H. Bending strain was used for alloy 800; axial strain was used for alloy 800H.

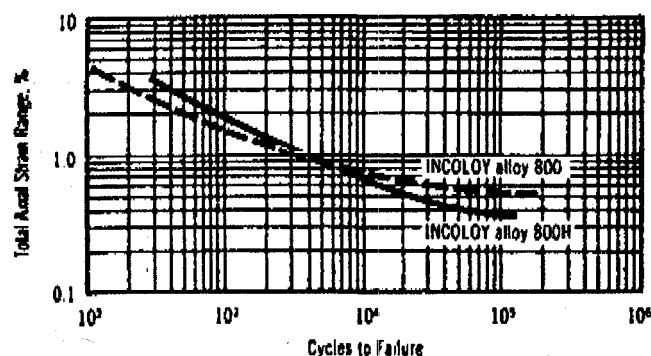


Figure 17. Low-cycle fatigue strengths of INCOLOY alloys 800 and 800H at 1000°F (540°C).

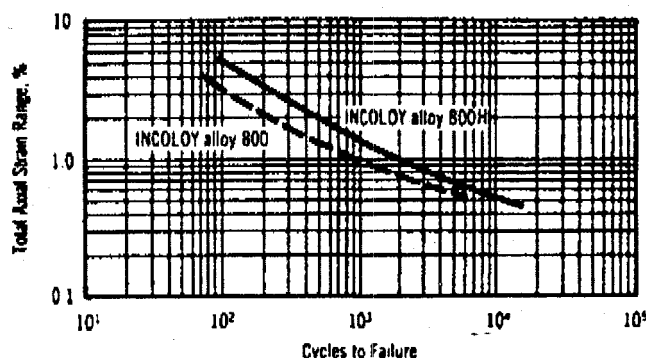


Figure 18. Low-cycle fatigue strengths of INCOLOY alloys 800 and 800H at 1200°F (650°C).

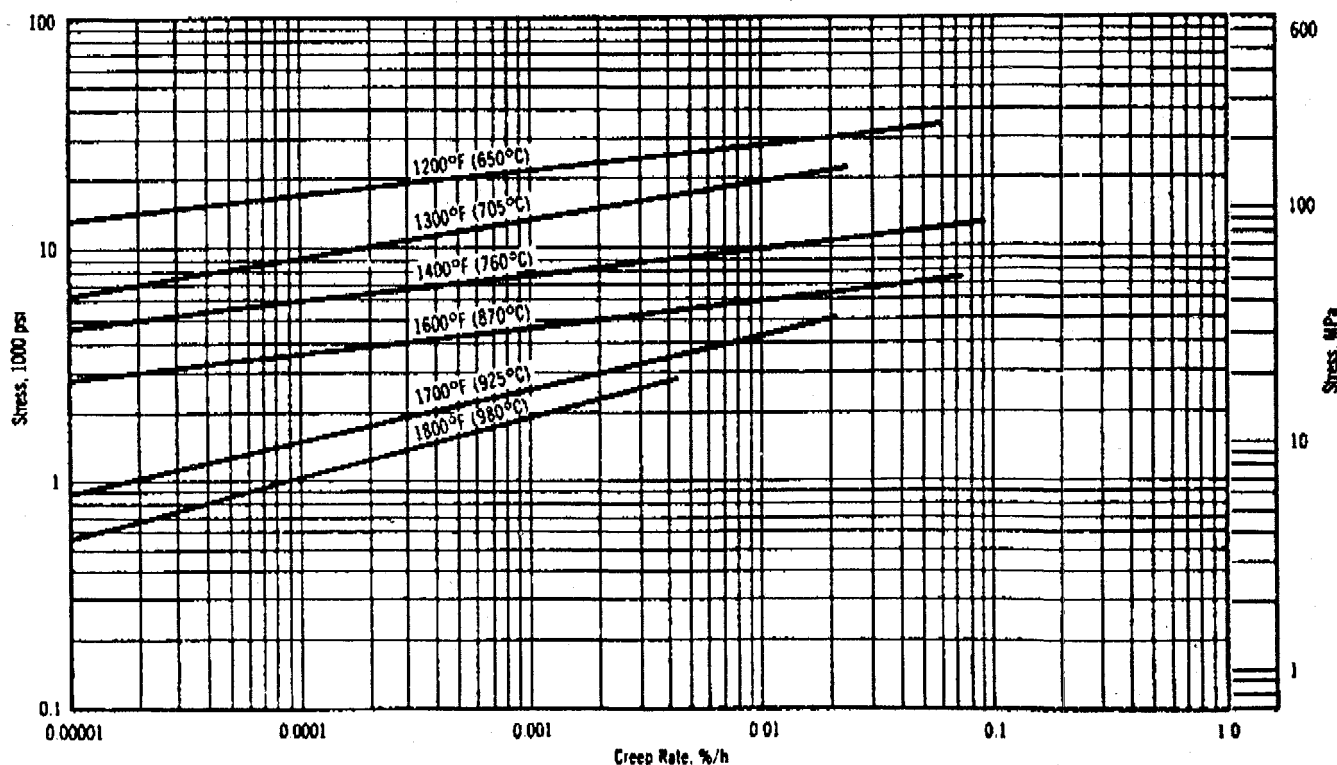


Figure 19. Typical creep strength of INCOLOY alloy 800H.

Rupture strength of the alloy is shown by the data plotted in Figure 20. Rupture-strength values for some specific temperatures and times are listed in Table 22.

ASME boiler and pressure vessel code

INCOLOY alloy 800H is approved under the Boiler and Pressure Vessel Code of the American Society of Mechanical Engineers. The alloy is approved under Section I (Power Boilers), Section III (Nuclear Vessels), and Section VIII (Pressure Vessels). Section I coverage is provided by Code Case 1325; Section III design values are contained in Code Case 1592.

Design stresses specified for alloy 800H by Section I and Section VIII, Division 1, of the Code (1977 edition) are listed in Table 23. Stress-intensity values for Class 1 components of nuclear vessels

Table 22—Representative Rupture-Strength Values for INCOLOY alloy 800H

Temperature		Stress to Produce Rupture in							
		10,000 h		30,000 h		50,000 h		100,000 h	
°F	°C	psi	MPa	psi	MPa	psi	MPa	psi	MPa
1200	650	17,500	121	15,000	103	14,000	97	13,000	90
1300	705	11,000	76	9,500	66	8,800	61	8,000	55
1400	760	7,300	50	6,300	43	5,800	40	5,300	37
1500	815	5,200	36	4,400	30	4,100	28	3,700	26
1600	870	3,500	24	3,000	21	2,800	19	2,500	17
1700	925	1,900	13	1,600	11	1,400	10	1,200	8.3
1800	980	1,200	8.3	1,000	6.9	900	6.2	800	5.5

Table 23—INCOLOY alloy 800H Design Stresses from ASME Boiler and Pressure Vessel Code, Section I and Division 1 of Section VIII

Maximum Metal Temperature		Maximum Allowable Stress in Tension			
		Standard		Conditional ^a	
°F	°C	psi	MPa	psi	MPa
100	38	16,200	111.6	16,200	111.6
200	93	15,400	106.1	16,200	111.6
300	149	14,500	99.9	16,200	111.6
400	204	13,500	93.0	16,200	111.6
500	260	12,900	88.9	16,000	110.3
600	316	12,200	84.1	16,000	110.3
650	343	11,900	82.0	16,000	110.3
700	371	11,700	80.6	15,700	108.2
750	399	11,400	78.6	15,400	106.1
800	427	11,100	76.5	15,300	105.4
850	454	10,900	75.1	15,100	104.1
900	482	10,700	73.7	14,800	102.0
950	510	10,500	72.3	14,600	100.6
1000	538	10,300	71.0	14,400	99.2
1050	566	10,100	69.6	13,700	94.4
1100	593	10,000	68.9	13,500	93.0
1150	621	9,800	67.5	11,200	77.2
1200	649	8,400	57.9	8,400	57.9
1250	677	6,900	47.5	6,900	47.5
1300	704	5,400	37.2	5,400	37.2
1350	732	4,500	31.0	4,500	31.0
1400	760	3,600	24.8	3,600	24.8
1450	788	3,000	20.6	3,000	20.6
1500	816	2,500	17.2	2,500	17.2

^a These higher stress values of up to 90% of yield strength at temperature may be used where slightly greater deformation is acceptable. The stresses may result in dimensional changes due to permanent strain and are not recommended for applications such as flanges of gasketed joints.

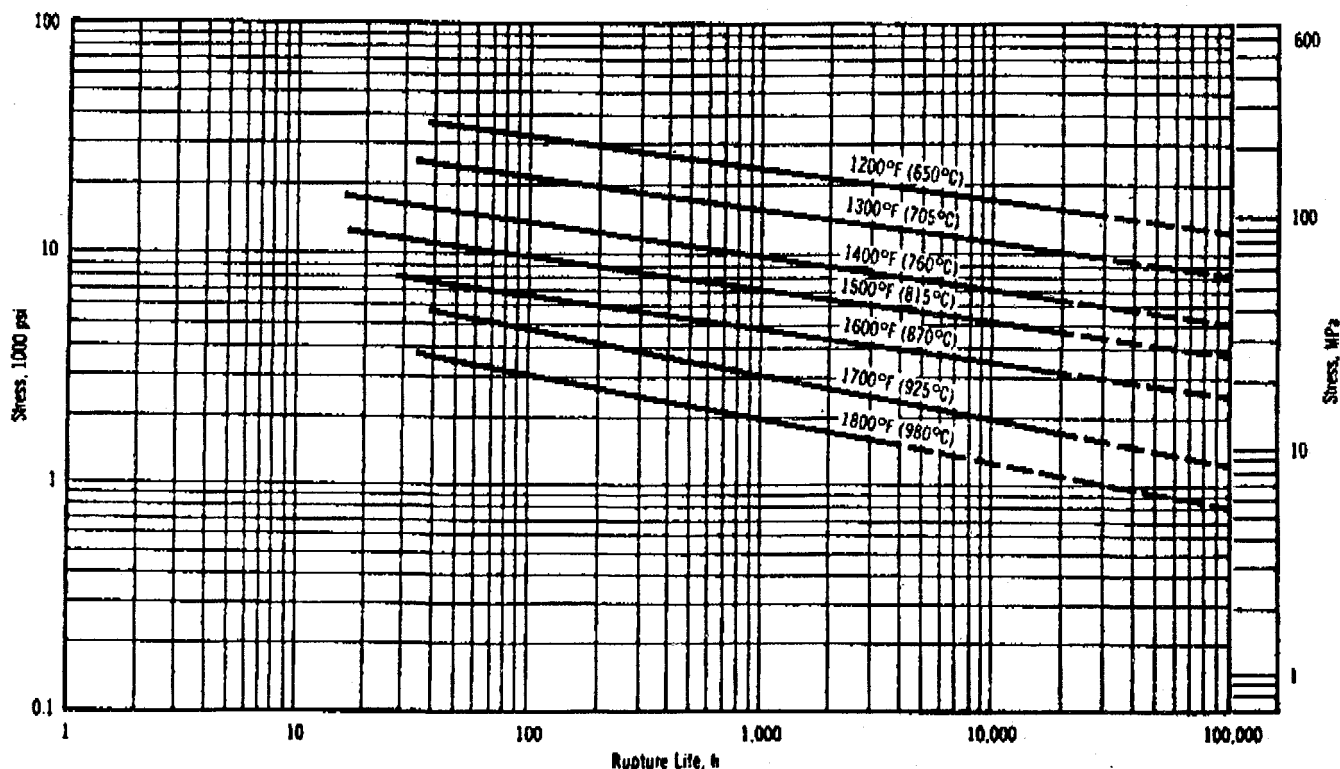


Figure 20. Typical rupture strength of INCOLOY alloy 800H.

constructed under Section III are given in Table 24. Also in Table 24 are values for Division 2, Alternative Rules for Pressure Vessels, of Section VIII.

Table 24 — INCOLOY alloy 800H Design Stress-Intensity Values from ASME Boiler and Pressure Vessel Code, Section III and Division 2 of Section VIII

Maximum Metal Temperature		Maximum Allowable Stress Intensity			
		Section III ^a		Section VIII, Division 2	
°F	°C	psi	MPa	psi	MPa
100	38	—	—	16,700	115.1
200	93	—	—	16,700	115.1
300	149	—	—	16,700	115.1
400	204	—	—	16,700	115.1
500	260	—	—	16,700	115.1
600	316	—	—	16,500	113.7
650	343	—	—	16,000	110.3
700	371	—	—	15,700	108.2
750	399	—	—	15,400	106.1
800	427	15,300	105.4	15,000	103.4
850	454	15,100	104.1	—	—
900	482	14,800	102.0	—	—
950	510	14,600	100.6	—	—
1000	538	14,400	99.2	—	—
1050	566	13,700	94.4	—	—
1100	593	13,500	93.0	—	—
1150	621	11,200	77.2	—	—
1200	649	8,400	57.9	—	—
1250	677	6,900	47.5	—	—
1300	704	5,400	37.2	—	—
1350	732	4,500	31.0	—	—
1400	760	3,600	24.8	—	—

^a Code Case 1592-9

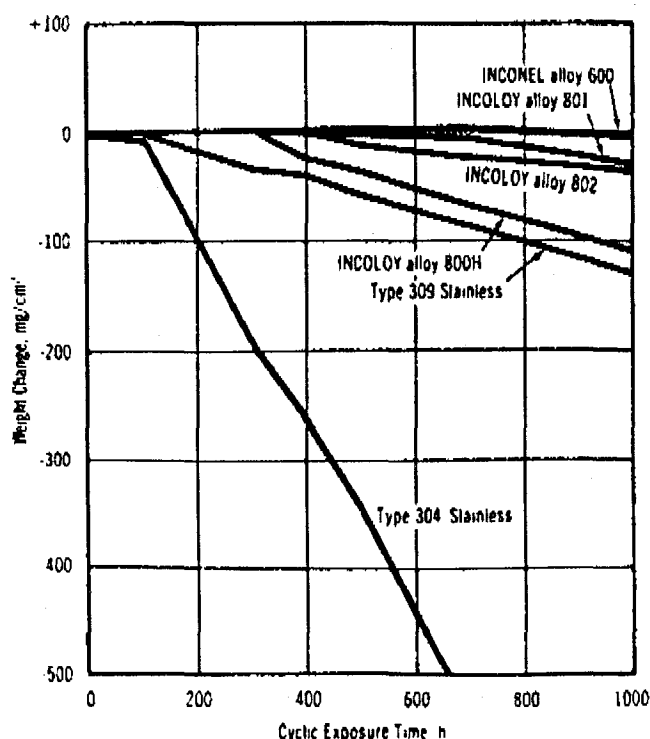


Figure 21. Results of cyclic oxidation tests at 1800°F (980°C). Cycles consisted of 15 min heating and 5 min cooling in air.

Metallography

The microstructure of INCOLOY alloy 800H is essentially the same as that of INCOLOY alloy 800. The phases described for alloy 800 also appear in alloy 800H. Because of its higher annealing temperature, however, alloy 800H usually exhibits a larger grain size.

Corrosion Resistance

Alloys 800 and 800H have the same nickel, chromium, and iron contents and consequently display the same corrosion behavior. Since alloy 800H is used for its high-temperature strength, corrosive environments to which the alloy is exposed normally involve high-temperature reactions such as oxidation and carburization. Corrosion resistance in aqueous environments and at moderate temperatures is discussed under INCOLOY alloy 800.

Oxidation

Because of its high chromium and nickel contents, INCOLOY alloy 800H has excellent resistance to oxidation. The chromium in the alloy promotes the formation of a protective surface oxide, and the nickel provides good retention of the protective coating, especially during cyclic exposure to high temperatures.

Figures 21 and 22 show the scaling resistance of alloy 800H in severe cyclic oxidation tests at

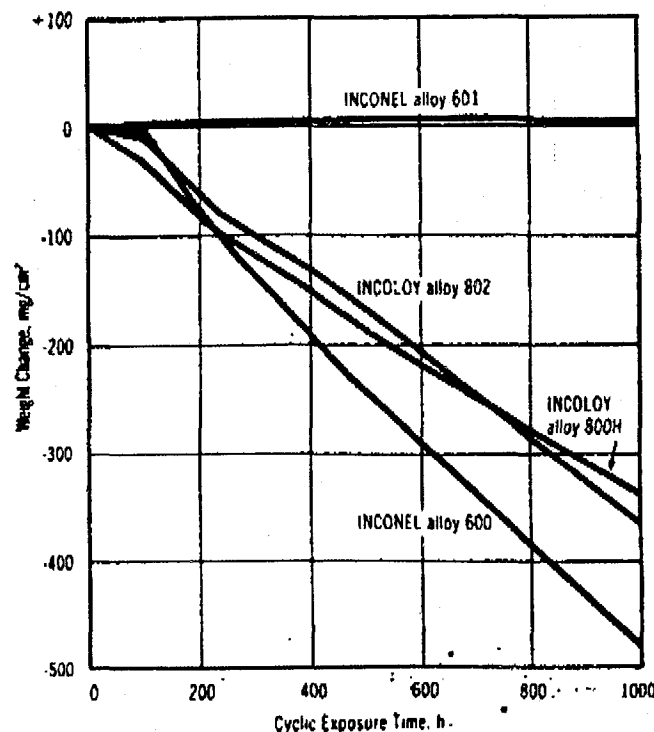


Figure 22. Results of cyclic oxidation tests at 2000°F (1095°C). Cycles consisted of 15 min heating and 5 min cooling in air.

1800°F (980°C) and 2000°F (1095°C). The tests were conducted in air and consisted of alternating exposure to temperature for 15 min and cooling in still air for 5 min. The specimens were subjected to 1000 h of cyclic exposure with periodic removal for weight-change measurements.

Table 25 gives the results of oxidation tests conducted in the fire box of a refinery furnace.¹⁵ The furnace operated at 1600°F to 2100°F (870-1150°C) and was fired by fuel having no sulfur. The samples were exposed in the furnace for 3 months.

In atmospheres that are oxidizing to chromium but reducing to nickel, nickel-chromium alloys may be subject to internal oxidation. The condition, which causes severe embrittlement, is characterized by extensive oxidation of chromium, leaving the remaining metal strongly magnetic. Susceptibility to internal oxidation is decreased by the addition of iron to nickel-chromium alloys.¹⁶ INCOLOY alloy 800H, with 46% iron, is resistant to internal oxidation.

Carburization

The high nickel content of alloy 800H provides good resistance to carburizing environments. Table 26 shows the alloy's resistance to carburizing atmospheres at 1700°F (925°C) and 1800°F (980°C). Table 27 indicates the superiority of alloy 800H over materials of lower nickel content in a

Table 25—Corrosion Rates in Furnace Atmosphere

Alloy	Corrosion Rate	
	mpy	mm/yr
INCOLOY alloy 800H	6.0	0.15
Type 310 Stainless	8.9	0.23
Type 309 Stainless	84.5	2.15
Type 304 Stainless	Complete Oxidation	

Table 26—Results of 100-h Gas-Carburization Tests in Hydrogen plus 2% Methane

Alloy	Weight Gain, mg/cm ²	
	1700°F (925°C)	1800°F (980°C)
INCONEL alloy 600	2.66	—
INCONEL alloy 601	2.72	4.32
INCOLOY alloy 800H	4.94	11.6
Type 330 Stainless	6.42	12.4

25-h gas-carburization test performed at 2000°F (1095°C). The test atmosphere consisted of 2% methane in hydrogen.

Table 28, results of 100-h carburization tests at 2000°F (1095°C), compares INCOLOY alloy 800H with some other alloys having high resistance to carburization. The atmosphere was composed of 2% methane and 5% argon in hydrogen.

Sulfidation

Because of its high chromium content, alloy 800H has good resistance to sulfur-containing atmospheres at high temperatures. Table 29 gives the results of sulfidation tests performed at 1110°F (600°C) and 1290°F (700°C) in an atmosphere of 1.5% hydrogen sulfide in hydrogen. The weight-loss measurements are for descaled specimens after 100 h of exposure. Data on the resistance of the alloy to hydrogen sulfide at lower temperatures are contained in Tables 14 and 15.

Table 27—Results of Gas-Carburization Tests at 2000°F (1095°C)
25-h Tests in Hydrogen plus 2% Methane

Alloy	Weight Gain, mg/cm ²
INCONEL alloy 600	2.78
INCOLOY alloy 802	4.54
INCOLOY alloy 800H	5.33
Type 310 Stainless	18.35
Type 309 Stainless	18.91

Table 28—Results of Gas-Carburization Tests at 2000°F (1095°C)
100-h Tests in Hydrogen plus 2% Methane and 5% Argon

Alloy	Weight Gain, mg/cm ²
INCONEL alloy 600	12.30
INCONEL alloy 601	16.18
INCOLOY alloy 800H	21.58
Type 330 Stainless	24.00

Table 29—Results of 100-h Gas-Sulfidation Tests in Hydrogen plus 1.5% Hydrogen Sulfide

Alloy	Weight Loss, ^a mg/cm ²	
	1110°F (600°C)	1290°F (700°C)
INCONEL alloy 601	15.6	79.3
INCOLOY alloy 800H	29.5	147.0
Type 310 Stainless	32.6	138.4
Type 304 Stainless	37.8	191.6

^a Descaled specimens.

Nitriding

Studies involving various nitriding environments have shown that the resistance of nickel-iron-chromium alloys to nitriding increases with nickel content.¹⁷ Although INCONEL alloy 600 (76% nickel) is usually preferred for nitriding service, INCOLOY alloy 800H (32% nickel) has good resistance to many nitriding atmospheres. Table 30 compares alloy 800H with several other materials in tests performed in an ammonia converter.¹⁸ The samples were exposed for 3 years to the atmosphere of 65% hydrogen and 35% nitrogen at 11,000 psi (75.8 MPa) and 1000°F (540°C).

Table 30—Results of Nitriding Tests in Ammonia Converter*

Material	Depth of Nitriding			
	1 Year		3 Years	
	in.	mm	in.	mm
INCOLOY alloy 800H	0.0054	0.137	0.0053	0.135
Type 310 Stainless	0.0088	0.224	0.0092	0.234
Type 309 Stainless	0.0095	0.241	0.0096	0.244
Type 446 Stainless	0.0417	1.059	0.0453	1.151
Type 304 Stainless	0.0427	1.085	0.0440	1.118

*Atmosphere of 65% hydrogen and 35% nitrogen at 11,000 psi (75.8 MPa) and 1000°F (540°C).

Table 31—Rupture Strengths of Welding Products (All-Weld-Metal Specimens) for INCOLOY alloy 800H

Welding Product	Temperature		Stress ^a for Rupture in					
			100 h		1000 h		10,000 h	
	°F	°C	psi	MPa	psi	MPa	psi	MPa
INCO-WELD A Electrode	1000	540	60,000	414	51,000	352	39,000	269
	1200	650	35,000	241	24,500	169	16,000	110
	1400	760	16,500	114	11,000	76	7,100	49
	1600	870	7,000	48	3,650	25	1,900	13
	1800	980	2,300	16	900	6	—	—
INCONEL Filler Metal 82	1000	540	58,000	400	52,000	359	47,000	324
	1200	650	36,500	252	27,500	190	20,500	141
	1400	760	16,000	110	11,500	79	8,300	57
	1600	870	6,800	47	3,500	24	1,750	12
	1800	980	2,700	19	1,250	9	570	4

*Values in bold are extrapolated

Table 32—Specifications for INCOLOY alloy 800H

Form	ASTM	ASME
Seamless Condenser Tubing	B 163	SB-163
Seamless Pipe and Tubing	B 407	SB-407
Rod and Bar	B 408	SB-408
Plate, Sheet, and Strip	B 409	SB-409
Forgings	B 564	SB-564

Working instructions

The heating, pickling, forming, and machining procedures described for INCOLOY alloy 800 also apply to INCOLOY alloy 800H. In cold forming, however, alloy 800H normally displays less resistance to deformation because the higher annealing temperatures used for the alloy produce greater softness.

Annealing

Alloy 800H is produced using annealing procedures that result in a minimum grain size of ASTM Number 5. Such annealing treatments are necessary to achieve optimum creep and rupture properties in the alloy. If alloy 800H is subjected to hot or cold forming, re-annealing may be necessary to restore creep and rupture strength or to prevent cold-formed parts from recrystallizing during high-temperature service. Temperatures for re-annealing depend on the amount of strain hardening present in the material. In general, however, annealing should be performed at 2100 to 2200°F (1150-1205°C) for a time commensurate with section size.

Joining

Alloy 800H has the same good weldability as alloy 800. Alloy 800H is normally used for applications requiring high creep-rupture strength, and it should be joined with welding products that have suitable strength characteristics at the intended service temperatures.

For temperatures up to 1450°F (790°C), INCO-WELD A Electrode is used for shielded metal-arc welding, and INCONEL Filler Metal 82 is used for gas-shielded welding. Table 31 lists rupture strengths of those weld metals at various temperatures. Filler Metal 82 is also used with INCOFLUX 4 Submerged Arc Flux for submerged-arc welding of INCOLOY alloy 800H.

For service temperatures over 1450°F (790°C), the optimum welding product depends on the specific temperatures involved and the properties needed in the welded joint. Consult Huntington Alloys for guidelines on the selection of welding products for applications at temperatures over 1450°F (790°C).

Available products and specifications

INCOLOY alloy 800H is available in all standard mill forms including rod, bar, plate, sheet, strip, shapes, and tubular products. Full information on available products may be obtained from the offices listed on the back cover.

Society specifications applicable to INCOLOY alloy 800H are shown in Table 32.